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The significance of *techné* in understanding the art and practice of electroacoustic composition

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The birth of electroacoustic music is associated with an era of creativity which is now firmly embedded in the past. As the years advance so the opportunities for evaluating the pioneering years of the medium become increasingly remote. Few can now claim first-hand experience of working with the technologies that shaped and influenced the evolution of the early repertory, and many commentators are content to see them consigned to the museum. Others are less sure, having become aware of a number of features that appear to have no parallels in the modern all-digital domain. This article is predicated on the proposition that the functional characteristics of the equipment available during the formative years materially influenced the ways in which composers developed their compositional aesthetic. By studying the characteristics of the resulting interactions, important clues emerge as to the true nature of this engagement. Central to this study is the nature of the *techné* involved in these processes of creativity, and the significance of this is evaluated in the context of establishing a case for further research in this area. Particular attention is paid to the role of the tape recorder in this context, in particular its influence on the development of spatialisation techniques.

1. INTRODUCTION

It is more than half a century since Max Mathews began his first tentative experiments in digital sound synthesis at Bell Telephone Laboratories, New Jersey. The technology employed has long since passed into obscurity, and only a select and inevitably diminishing group of pioneers is now able to provide a conduit to this bygone era. The formative era of electroacoustic music during the 1940s and 1950s fares little better. Although some of the devices employed still exist in working order, very few students studying the medium since the early 1990s are likely to have encountered the delights and frustrations of the tape recorder and razor blade, let alone the myriad of other devices which predate the first generation of voltage-controlled synthesizers, in turn now very much a rarity.

The situation regarding access to the musical repertory is just as problematic. A few works dating from these early years have been reissued as CDs, but the majority of commercial pressings remain as vinyl recordings, long since deleted from record catalogues. The situation as regards access to the original master tapes is if anything worse. Many of these have disappeared over the years as studios have closed and those that survive are often in a poor physical state as a result of the passage of time. The efforts of organisations such as the Electronic Music Foundation (New York) to preserve and make accessible this important musical legacy for posterity are strongly to be encouraged, and it is not too late to make further progress in this regard. The remaining window of opportunity, however, is finite.

One unfortunate tendency of previous lines of enquiry, and more particularly the ways in which the findings have been subsequently interpreted by teachers and practitioners, is that judgements relating to the relevance or otherwise of this pioneering era have often been based upon incomplete criteria. Much has been written on the history of the repertory and the theoretical considerations which informed the development of an associated aesthetic. Considerable attention has also been paid to the technological principles that shape and determine the practical processes of sound production and transformation. What is often neglected, however, is the true nature of these early technologies, in particular the ways in which their functional characteristics shaped and influenced the creativity of composers.

2. ART AND PRACTICE: THE ROLE OF *TECHNÉ* AND A STRATEGY FOR FURTHER STUDY

The seeds for what has become an increasing disjunction were sown long ago. Gianmario Borio, writing in 1993 on the aesthetics of electronic music in the 1950s, concluded that:

> The appearance of electronic music at the beginning of the 1950s had presented a challenge for musicology. It focused on the need for a new evaluation of the role played by techniques and technologies in the creative process, and this implicated a revision of some aesthetic principles. . . . The question whether a specific approach on the aesthetics of electronic music is desirable or even necessary, seems to have received a negative answer by the attitude of composers themselves after 1960. (Borio 1993: 85)

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Although his conclusion is perhaps a little overstated, the underlying argument is nonetheless significant, since it draws attention to the considerable aesthetic challenges posed by a medium where notation, at least in the conventional sense, is replaced at best by functional descriptions of the technical procedures employed in realising a work, and at worst just the acoustic results. 'One wonders, how much specialised knowledge is required in order to reconstruct the structural level, even if only a general form' (*ibid.*: 81). The importance and value of quantifying and reflecting upon both the theoretical and practical components of the compositional process as a means of advancing aesthetic debate led to spirited arguments during the formative years, involving not only electroacoustic composers but also members of the wider artistic community.

Notwithstanding this highly proactive level of engagement, the significance of studying the nature of the interactions between electroacoustic composers and the tools of analysis and re-synthesis at their disposal was not universally recognised. As the years advanced and the technologies gained in both versatility and in sophistication, so these issues were increasingly side-stepped. Some influential commentators, however, became concerned with what they perceived as impediments to creative progress and accordingly rekindled the debate. Writing in 1977, Pierre Boulez observed that:

> Rather than ask themselves the double question, both functional and fundamental, whether the material is adequate to the idea and the idea compatible with the material, [musicians] give way to the dangerous temptation of a superficial simple question: does the material satisfy my immediate needs? Such a hasty choice, detached from all but the most service functions, certainly cannot lead far, for it excludes all genuine dialectic and assumes that invention can divorce itself from the material, that intellectual schemas can exist without the support of sound. . . . [Invention] should not be satisfied with a raw material come upon by chance, even if it can profit from such accidents and, in exceptional circumstances enlarge upon them. (Boulez 1977: 9–11)

These observations reflect a particular point of view, and it is illuminating to probe some way beneath the surface. In effect, the article amounts to a mission statement for IRCAM, specifically the concern of the author to place the technology of the computer centre-stage in the quest for 'a common language which would take account of the imperatives of musical invention and the priorities of technology' (*ibid.*: 12). Boulez argued strongly for a fully integrated environment, considering it 'absolutely necessary . . . that we should move towards global, generalisable solutions' (*ibid.*: 14).

Such a perspective was to become central to the work of IRCAM. It is important, however, to bear in mind that Boulez enjoyed the luxury of an environment where a fruitful symbiosis between artistic aspiration and the construction of the technical means necessary to realise such ambitions was a practical proposition. This creative empowerment fostered a culture within the institution that all but ignored what had gone before. In thus choosing to ignore the achievements of others working in less favourable circumstances, faced with circumventing the practical limitations of whatever technologies were at their disposal, an important opportunity was lost. A key purpose of this article is to establish if there are valuable lessons to be learnt from these experiences, not least in terms of informing future directions, both technical and musical.

This vision of IRCAM's mission provides a defining point of reference for the central focus of this critique. As Tod Machover observed in 1984, a key concern of this institution was to provide 'a common meeting ground not only for scientists and musicians . . . but one for composers and their colleagues' (Machover 1984: 1). This led him to reflect whether 'a typical musical bent, an "IRCAM style" had begun to emerge from the studios'. In conjecturing that 'this has not been the case, and that musical diversity is, in fact, much more common at IRCAM than standardisation', he suggests that 'the diversity is due also to the neutrality of technology, which offers powerful tools for exploration and creation but does not orient the composer in any particular musical direction' (*ibid.*: 1–2).

This proposition is open to challenge. Carlos Palombini, in a critique published in 1998, undermines Machover's advocacy of neutrality as a universal panacea for success, citing the following observation from Heidegger: 'We are delivered over to technology in the worst possible way when we regard it as something neutral: for this conception of it makes us utterly blind to the essence of technology' (Palombini 1998: 35).

Heidegger's arguments were articulated in 1954, right at the height of the early debates about the aesthetic justification for electroacoustic music as a creative medium and long before the technical sophistication of IRCAM and the implications thereof could have been envisaged. His recall of the Greek concept of *techné*, and how it became synonymous with the processes of creative development and dissemination, acted as a catalyst for others. Adorno, for example, writing just four years later observes that:

> The meaning of the Greek word *techné* from which both 'technique' and 'technology' are derived offers an indication of the unity of this concept with art. If art is the external representation of something internal, the concept of technique embraces everything which pertains to the realisation of that interior substance. In the case of music, not only the realisation of spiritual substance

> in the score is involved, but the transformation which makes this score accessible to sensory perception as well. In short, both production and reproduction are involved. Musical technique embraces the totality of all musical means: the organisation of the substance itself and its transformation into a physical phenomenon. (Adorno 1958: 11)

If this alternative proposition has currency, it follows that the functional characteristics of technology will almost invariably influence the creative process, and therefore cannot be ignored in any evaluation of the resulting aesthetic.[1]

Agostino Di Scipio has succinctly identified the fundamental dilemma which continually confronts electroacoustic composers:

> How can I use the available existing task-environment to realise my own ideas of composition?

or

> How can I design the tools that are necessary to realise my own idea of composition? (Di Scipio 1995a: 37)

It has been the tendency to favour the former approach rather than the latter which underpins the criticisms of Boulez highlighted above. Although such observations were by no means new, Di Scipio's further consideration of these issues viewed from the perspective of an ethnomusicologist sheds useful additional light on their significance, most notably the need to 'grasp something of the composer's conception of sound materials and the cognitive relation between sound materials and musical form' (*ibid.*). In a subsequent article, considering specifically the centrality of *techné* for an aesthetic approach to electroacoustic music, he develops this hypothesis further:

> In electroacoustic music the making of a work is, to some extent, captured and documented in the technical tools adopted or specially designed by the composer. The composer's relationship to the materials and the forms of his/her art (which to me is the very object of any analytic view) are mediated by those design tools – tools of work and thought. They cannot be considered foreign to an aesthetic approach, for they do reflect the artist's knowledge and his/her conception of sound and music, and to some extent could be studied. The technological tools embody the theory of music behind a composer's attitude and work (knowledge of the field), and objectify the cognitive strategies involved in using the theory (action knowledge). (Di Scipio 1995b: 374)

There are alternative, but not necessarily incompatible views on the nature and importance of the interactions that occur between electroacoustic composers and their tools. For example, Leigh Landy has observed that:

> As technology seems to be at the heart (it does represent at least a limb) of electroacoustic music, it comes as no surprise that its history is often presented within a technology or theory-based wrapper. Yet, as said, the history of this music (and its prehistory) is not solely technology based or even necessarily technology driven. (Landy 1999: 64)

Landy's concerns are not so much to do with the fact that creativity and technology become inextricably linked in the realisation of electroacoustic works, but the manner in which such considerations have been evaluated in musicological discourse: 'Does it suffice to illustrate theory or studio equipment or do we need to know more about how the music has been constructed?'(*ibid.*: 63). It is the latter issue that is to be considered here. To paraphrase Landy, explaining the nuts and bolts of how an electroacoustic work has been constructed is only the starting point. Understanding the *techné* that shapes and influences how such processes are selected and applied is the much bigger and more valuable goal. 'Rewinding the tape, are we overemphasising a little the relevance of the exciting 1948–50s period half a century later?' (*ibid.*: 63). We shall see.

The challenges to be faced in addressing such issues are significant, no more so than in the consideration of an era of creative engagement so far removed from present day experiences. The current context only permits an exploratory investigation, and it is therefore important that the arguments for conducting more rigorous and extensive research are put forward within a clearly defined context. In necessarily selecting a specific area of technology for this purpose, there is a risk that the focus will be too narrow and therefore not sufficiently representative for more wide-ranging conclusions to be drawn. In choosing key aspects of the technology associated with the tape recorder for special study, however, the chances of such an unsatisfactory outcome are significantly reduced.

3. THE DEVELOPMENT OF SOUND IMAGING AND SPATIAL PROJECTION TECHNIQUES

For more than thirty-five years, *circa* 1950–1985, the reel-to-reel tape recorder provided the primary tool for registering and manipulating electroacoustic materials. Its functional characteristics and practical limitations thus determined the *modus operandi* for the overwhelming majority of composers during the formative post-Second World War years. Whereas recorded magnetic tape reveals no visual clues as to the nature of the recorded material, a precise and easily identifiable relationship between the duration of a sound extract and the physical length of tape required

[1]Put another way, *Techné*, to paraphrase Heidegger (1954: 13), is concerned with the revealing or bringing-forth of creative ideas through technology, rather than the means by which they are created. Palombini's succinct analysis of Heidegger's *Ge-stell* in his article, and its relevance to the study of *techné*, provides useful background reading for many of the ideas that will be pursued in the current context.

to register the information establishes a very special working environment. The freedom to start and stop recorders at will, while at the same time dynamically regulating the amplitude levels of these reproduced materials, cultivated an art of performance in the realisation of works which is very remote from any of the practices normally encountered in the highly integrated world of the digital computer studio.

One important consideration is the nature of the recording facilities available to electroacoustic composers during the pioneering years. Up until the mid-1950s, conventional studios were designed for mono recording only. Although prototype stereo tape recorders became available during the first part of the decade, it was not until the advent of the stereo long-playing record *circa* 1958 that commercial production began in earnest. As a consequence, a significant proportion of the early repertory was produced using mono recorders. This had major implications, both in terms of the techniques that were used to build up composite sounds from individual components, and also the very special challenges that had to be overcome in creating works that use two or more playback channels.

The first concert performance of *Symphonie pour un homme seule* by Pierre Schaeffer and Pierre Henry in the École Normale de Musique, Paris, on 18 March 1950 is a case in point. This event brought the creation and spatial dissemination of electroacoustic music into the concert hall in a highly dramatic fashion, the audience witnessing the synthesis of the work both aurally and visually, the operators being required to run about the stage area starting and stopping the contributing recordings, reproduced via a spatially distributed network of monophonic playback systems, each assigned to a different amplifier and loudspeaker. Important aspects of the *techné* associated with the synthesis and spatialisation of this work thus became a shared experience.[2]

Across the Atlantic, similar techniques were being pursued by composers associated with John Cage's early project, *Music for Magnetic Tape*. Their works were written for either four or eight independent sound channels, to be reproduced simultaneously via an array of mono tape recorders and amplifiers, the associated loudspeakers being spatially distributed around the listening area, typically in a circular format. Notable examples include Cage's *Williams Mix*, completed in 1952, and *Octet 1 for Eight Loudspeakers*, composed by Earle Brown in 1953. Without any physical means of achieving and maintaining accurate synchronisation between the tape recorders, each performance becomes a unique and unrepeatable experience. Indeed the inevitable differences which result from one performance to another were considered by the composers to be an essential ingredient of the underlying aesthetic. The tape recorders, in essence, become contributing members of a performing ensemble.

The techniques of sound imaging explored by composers at the Studio di Fonologia Musicale, Milan provide another illustration of compositional practices which have long since been forgotten. This studio, directed by Luciano Berio from its foundation in 1955 until 1961, was by far the most generously equipped European studio of its time, both in terms of audio synthesis and signal processing devices and also the provision of stereo capabilities from the outset. Prior to the introduction of a four-track tape recorder in 1959, first used for compositions such as *Momenti* (1960) by Berio, and *Omaggio a Emilio Vedova* (1960) by Luigi Nono, works were produced using a hybrid recording environment consisting of a bank of six mono recorders and two stereo recorders.

What is notable here is the very precise and aurally effective use of sound imaging explored by the early Milan composers in their two-channel works. Indeed, the use of the more familiar descriptor 'stereo' is somewhat inappropriate since the image space was usually partitioned into either two fixed loci (mono left – left-hand speaker only, and mono right – right-hand speaker only), or three fixed loci (mono left, mono right, plus a mono signal projected to both speakers with equal volume, resulting in a dead centre image). Rather than adopt the essentially asynchronous approach used by Cage and his associates, the majority of the early Milan composers micromanaged the spatial interactions between the contributing sound streams as an integral part of the creative process, creating a continuum between sharply differentiated material and what essentially were quasi-stereo effects where sound images mapped to one of the loci are ghosted, using subtly manipulated time delays, to another locus.

The distinctive approach to sound imaging raises an important question. Was it the case that the manipulation of monophonic sound sources in the manner described was driven by the compositional aesthetic, or was it the technology itself that drove the creative process? The pragmatic answer is that we cannot be entirely sure. No detailed records of how the works were actually constructed have survived, and from this distance in time, recollections are at best anecdotal and thus of limited reliability. There are, however, some technical documents (see, for example, Lietti 1956) that can at least offer some useful clues.

One factor is the role played by the technical assistants, for there is strong evidence to suggest that they played a key role as mediators between composers and

[2]It should be noted that this work involved the performance of disk phonograph recordings, since the studio had yet to acquire any tape recorders. In terms of the *techné*, however, in particular the physical engagement with the start and stop controls of the recorders, the significance of this consideration is only marginal.

the practical techniques used to realise their ideas.[3] The implications of this are potentially far reaching, for there is every reason to suppose that their role was anything but neutral. To electroacoustic composers, not least those associated with this pioneering era, the notion that their works might have been shaped creatively not merely by the technology available but also those who assisted them is very hard to accept. It is indeed very striking how few, when recollecting their studio experiences, even acknowledge that their technical assistants played any part whatsoever in the creative process.

The functional characteristics of the technology itself are of particular relevance here. For example, in considering the ways in which tape recorders were used at this time to assemble electroacoustic compositions, one significant factor is the operational design of the studio mixer. In the case of mixers manufactured since the early 1970s, it is usually the case that incoming audio signals can be mapped to any point within a stereo image by using a simple rotary control, regulating the relative distribution of the signal levels between the associated pair of loudspeakers. Back in the 1950s, such facilities were rare, often requiring an invariably cumbersome and often unsatisfactory workaround. One consequence of this situation was a tendency, especially in the formative stages of composition, to bypass the mixer altogether and simply connect the tape recorders directly to individual speakers in the studio. Thus the very processes of selecting and shaping materials for a composite sound led to modes of listening and critical evaluation that involved the use of multiple point source sound projection.

In terms of conducting aural analyses of these works, archival research elicits a useful if at times hard-to-find legacy of commercial recordings. Some caution, however, has to be exercised in drawing any definitive conclusions on the uses of spatial projection from aural analyses of these recordings, since there is a strong probability of often subtle but nonetheless potentially significant discrepancies between the original studio master tapes and what was actually released in the public domain. Berio's *Thema – Omaggio a Joyce* (1958) is a notable illustration of this. For reasons almost entirely attributable to the associated technology, none of the commercial pressings of this work achieves the clarity of image separation present in the original stereo master tape. Whereas the degree of 'cross talk' or leakage of sound information between the two adjacent tracks of a stereo magnetic tape recording is relatively small, this is patently not the case when this information is transferred to a stereo record groove. In the latter case, the nature of the recording medium reduces the maximum degree of channel separation to such an extent that the true isolation of a sound in either channel cannot be achieved.[4]

A further limitation arises from the tracking difficulties encountered in any situation where a sudden burst of sound information in one channel is not modified by suitably compensating activity in the other. In such a situation the resulting asymmetry in the profile of the groove walls can cause the stylus to jump out of the groove. To reduce this possibility, record manufacturers would invariably limit the maximum possible degree of channel separation by deliberately introducing an element of cross channel blending, reducing still further the possibility of reproducing the original perspective. The reduced degree of spatial differentiation encountered in the commercial recordings of works such as *Thema* thus compromises the original intentions.

The extent to which spatial projection became so central a consideration for the Milan composers can be further corroborated by studying contemporary commentaries by those who had occasion to work there. One of the most revealing is a detailed account by Marc Wilkinson of his experiences over a two-month period in 1957. This contains the following observations:

> The listener can [perform] the act of hearing. In good conditions, surrounded by a stereophony of sound projectors, his mind will automatically concentrate on different sets of projectors in turn. Each 'performance' of the work will bring new visions, for the mind will almost certainly rearrange the sequence of its concentration in space; for that matter, the listener can 'interpret' the music by moving about within the confines of the stereophony during performance, thereby consciously creating states of imbalance between the component constructions in sounds simultaneously projected from the different spatial origins. (Wilkinson 1958: 48)

Here the thinking logically extends the aesthetics of sound projection a stage further, and in so doing encapsulates a yet wider range of compositional practices, including those already explored in the context of the 'Music for Magnetic Tape' project. Cage indeed subsequently visited the studio in 1958 to compose *Fontana Mix*, based on a kaleidoscope of sound fragments from diverse sources recorded onto four mono tapes, played back simultaneously via four playback systems with independent loudspeakers.

The development of commercial four-track recorders facilitated a change in composing practices at Milan from 1959 onwards since it was at last possible

[3]The prominent contributions of the chief technician, Marino Zuccheri, are noted by Chadabe (Chadabe 1997: 57–62). See also Wilkinson (1958) for a contemporary and at times revealing account of the working environment.

[4]The maximum channel separation possible in a stereo groove at 1 kHz is about 35 dB. The performance of most pickup cartridges reduces this to about 25 dB.

to work synchronously with a truly stable multi-channel sound environment. The distinctive characteristics of point source imaging, however, were by no means abandoned, many composers taking advantage of the new facilities to refine these techniques still further. Two of the other major European studios active at this time had acquired experimental multi-track recorders some years before. In both cases, however, issues of unreliability were to restrict their practical use.

An experimental three-channel tape recorder had been developed in 1951 as part of an upgrade for Pierre Schaeffer's Club d'Essai studio for *musique concrète* in Paris. This device consisted of a specially constructed tape deck using three reels of tape, fed as three parallel strips through a single three-layer transport mechanism, with one set of erase/record/replay mono tape heads for each track (Moles 1960: 77). Whereas the common drive capstan ensured a reasonable degree of synchronisation, absolute precision, however, was not possible, and the tape mechanism proved cumbersome and less than reliable. This latter consideration generally restricted its use to intermediate processes of composition, for example, layering up to three components of a composite sound prior to mixing them together permanently as a mono recording. It is a matter of some curiosity, nonetheless, that none of the works completed at the studio were mastered via this recorder in a multi-channel format (Davies 1968: 69–72).

The Cologne studio went one stage further with the purchase of a pioneering four-track tape recorder in 1953 (Enkel 1954: 10–11). This unique machine, manufactured by Albrecht, consisted of two side-by-side two-track tape transports, using specially manufactured magnetic tape with perforations along one edge which engaged with linked sprockets. The original design of the studio linked this recorder to a discrete three-channel playback system in the main transmission studio, using eighteen loudspeakers organised into three groups, one group located at the front of the main listening area, and the other two along the side walls (*ibid.*: 11–12).

It would appear, however, that this facility aroused little or no interest amongst the composing community, with no record of any work ever being composed using this playback format (Davies 1968: 49–50). As in the case of the Paris studio, however, this special recorder proved especially useful for building up sound textures consisting of up to four different elements, to be subsequently mixed down to a single mono track. It was Stockhausen's *Gesang der Jünglinge* (1955–1956) that finally broke the mould, both in terms of escaping from the extreme musical formalism advocated by Herbert Eimert, the studio director, and also in exploring the possibilities of using a fully synchronised four-channel format for the spatial projection and manipulation of sounds as an integral component of the compositional process.

Although the form and structure of this work have been written upon extensively by a number of commentators (see, for example, Maconie 1990 and Harvey 1976), significantly less attention has been paid to the technical procedures he employed and their significance for the compositional process. Such research is especially challenging since no complete realisation score was ever produced, and for many years only some of the sketches were available for further study. The publication of a full facsimile of these by Stockhausen Verlag in 2001, however, has created new opportunities for gaining a greater insight into the creative and technical procedures used to realise this work.

Important groundwork for such a line of enquiry was prepared by Pacal Decroupet and Elena Ungeheuer in 1998 (Decroupet and Engeheuer 1998). In an initial consideration of the compositional issues that are addressed in this work, they highlight the all-important seeds of transition from essentially deterministic and static timbres towards the fluidity of expressive techniques that explore 'the overall directional tendencies of movement: the change from one state to another, with or without returning motion, as opposed to a fixed state . . . deriving the shapes of articulation for sound complexes in time from the articulation of a sound, in phases of attack, sustain and decay' (Decroupet *et al.* 1998: 98–9). These directional tendencies of movement concern not only the shaping of timbres but also their spatial manipulation within the listening area.[5]

In their analysis of the compositional process, Decroupet and Ungeheuer succinctly identify the creative dynamic which results from using serial procedures in a highly regulated form, for example to carve blocks of rhythmic spectra and to group formants in combination with statistically inspired procedures in order to regulate the evolution of timbre. They also recognise the significance of spatial articulation, identifying some of the key processes that emerged from Stockhausen's art of composition in this context, noting, for example, his use of both focused and distributed sound images to establish a continuum in terms of degrees of intelligibility, exploring the highly controllable characteristics of the so-called 'cocktail party effect', where the brain can more easily analyse sound complexes where individual components arrive at the ear from different directions, rather than as a merged image from just one direction. This characteristic, to return to an earlier discussion, is the very essence of the technique of distributed point source sound projection:

[5]The work was originally conceived in a five-channel format, the fifth channel to be provided by an additional mono recorder connected to a speaker in the ceiling. See Tannenbaum (1987: 23–4).

> The electronic and vocal parts . . . have a common denominator: each layer being heard in one loudspeaker, the distinction of the components of the polyphony is, if not easy, at least possible. On the other hand, the choral and impulse swarms packed together in compact blocks assigned to only one point in the hall . . . make impossible any attempt to distinguish the components. . . . Where the grouping of intensity . . . would normally bring about a complete and utter explosion, it is the spatialisation which intervenes to clarify the composition of timbres by allotting to certain loudspeakers all the variants of one category of timbre and by concentrating the irregular changes in only one loudspeaker. (*ibid.*: 128)

Having unlocked this door to a deeper understanding of the true creative significance of the spatialisation techniques employed here, Decroupet and Ungeheuer tantalisingly fail to enter. Crucial considerations are bypassed, for example how were the sound materials actually mapped to the loudspeakers, and to what extent did the operational characteristics of the studio, not least in terms of the very basic facilities available for audio mixing and channel routing, influence and ultimately constrain the compositional process? From even a preliminary study of these considerations it is clear that this is fertile ground for further research.

Whereas *Gesang der Jünglinge* proved to be a landmark work in terms of the use of fully synchronised multi-channel sound projection, it was Stockhausen's *Kontakte* (1959–1960), for four-channel tape, piano and percussion, that demonstrated the true potential of combining fixed point, multi-channel sound projection techniques with the spatial movement of sounds. For all the sophistication of modern multi-channel software tools for manipulating the location of sound images, for example IRCAM's *Spatialisateur* or SPAT (Manning 2004: 398–9), the aurally distinctive characteristics of dynamic sound projection via Stock hausen's specially designed *Rotationslautsprecher* are all the more dramatic precisely because of his continuing reliance on monophonic rather than stereophonic sounds.

The *Rotationslautsprecher* allowed sound images to be rotated in either direction within a two-dimensional acoustic space marked out by four loudspeakers at the corners of the listening area, by the simple expedient of manipulating a single loudspeaker on a rotating table, positioned within a quadrant of microphones (Chadabe 1997: 41). By this time, the studio had purchased a four-track Telefunken tape recorder (Tannenbaum 1987: 21), thus at last securing a reliable environment for working with multiple channels. The compositional process, however, was still essentially incremental, building up the composite sound field channel by channel, using the mono tape recorders to assemble the component materials. Although a sense of both breadth and depth is given by the judicious and selective use of stereo enhancement via an EMT plate reverberation unit, the primary foreground imaging is once again achieved by spatially mapping clearly differentiated monophonic sources.

The exceptional clarity of this information, not least in terms of the proactive engagement with the brain's ability to discriminate and assimilate highly directional information from different points of the compass, heightens the impact of the rotational images superimposed via the *Rotationslautsprecher*. These also have distinctive characteristics directly attributable to the design and practical operation of this device. The sense of movement is heightened by the Doppler effect that is generated as the sound from the loudspeaker moves through space from one microphone to the next in the quadrant. In addition, the use of a special projection cone fitted to the front of the loudspeaker to concentrate the location of soundfield adds another dimension to the process. Instead of generating a sense of smooth rotation, the resulting sound images vary in their concentration, becoming closely focused when directly coincident with a microphone and most diffuse at the mid-point between any two microphones. Thus a key characteristic of point source sound projection is partially retained as successive loudspeakers produce concentrated bursts of sound.

Whereas many of the functional characteristics of this device can be simulated using modern computer technology, there is one important respect in which the latter cannot accurately reproduce an important ingredient of the associated *techné*. The *Rotationslautsprecher* was a physical performance tool, operated directly by the hand actions of the composer, rotating the table faster or slower, and subject in addition to the frictional forces and the inherent inertia of the loudspeaker table itself.

The significance of this device in the composition of *Kontakte* and its method of construction focuses attention again on the conundrum identified by Di Scipio in terms of whether a composer uses the available task-environment to realise compositional ideas and thus inevitably faces some element of compromise, or instead seeks new tools designed specifically for the purpose (Di Scipio 1995a: 37). It would seem evident in this case that the *Rotationslautsprecher* was the product of the latter approach, but this still leaves the question, why this particular design?

Other design principles for dynamically manipulating sound images between distributed loudspeakers had already been explored elsewhere, notably the *potentiomètre d'espace*, developed in 1951 by Jacques Poullin for Pierre Schaeffer in Paris (Poullin 1953). This consisted of a small hand-held transmitting coil and four wire receiving loops arranged around the performer in a tetrahedron, representing in miniature the location of the loudspeakers in the auditorium. Moving the coil about within the tetrahedron modulated the induction signals in the receiving loops, this information being applied to the electronic amplitude

controls regulating the distribution of the sound source between the loudspeakers.[6]

The engineers at Cologne were well aware of alternative technologies. Indeed they had already developed an automated system for the spatial manipulation of signals fed to the loudspeakers of the original three-channel studio playback system, using frequency controlled switches which responded to tones recorded on the fourth track of the Albrecht recorder (Enkel 1954: 11–12). The design and functional characteristics of the *Rotationslautsprecher* are so distinctive that the more likely reason was a compositional imperative, predicated on developing the techniques of point source sound mapping used in *Gesang der Jünglinge* in ways which would not obfuscate the heightened perceptual clarity and ultimate complexity that could thus be achieved.

The construction score of *Kontakte*, which describes the processes of synthesis in intricate detail, provides fertile ground for such lines of enquiry. This information, however, can only provide part of what needs to be evaluated here. It is not sufficient simply to identify what technical procedures were used to distribute the contributing sound materials within the soundfield. A true insight into the creative process requires an understanding of how these procedures were used, in other words investigating the nature of Stockhausen's *techné*. The proposition here is that important clues in this context are to be found in the work itself, requiring both subjective and objective analysis of the sonic results.

Here again, the constraints of the commercial recording industry have conspired to greatly devalue the true characteristics of this landmark work. Having been conceived from the outset as a four-channel work, the necessary reduction into a stereo format had far-reaching consequences. It is not generally known that Stockhausen withdrew the first stereo release of the tape-only version of the work in order to replace it with a remixed version. The buying public were none the wiser since DGG used exactly the same record number (DGG 138 811) and cover. For the first version, the back left and front left channels are simply collapsed into a single left-hand channel, the same technique being applied to the two right-hand channels. All the spatial characteristics associated with images between the side pairs of channels were thus completely lost. The result in terms of the continuously rotating sounds is an unsatisfactory pulsing oscillation between the two stereo channels with pauses at each extremity as a result of the loss of all back-to-front and front-to-back movements. For the second version, a more satisfactory sense of continuous movement is achieved by panning the four channels equidistantly across the stereo channels, thus achieving a much smoother left–right representation of the rotational effects.

Even the latter version, however, loses vital aspects of the spatial perspective of this work, the significance of which can only be appreciated in the original four-channel format. A study of the latter reveals that all manner of subtleties are employed at a 'micro' level, for example, projecting two different mono sound sources simultaneously across the field of listening at right angles, using paired and diagonally opposite speakers. Alternatively the projection of the same signal from all four speakers creates the sense of the sound being physically located at the centre of the listening area. More pronounced stepwise rotations of images were also created by exploiting the short delay that occurs when tape passes from the record head to the playback heads of a tape recorder. By chaining the playback head of the first track of the four-track recorder to the record heads of the second, and repeating these connections to create a loop, short bursts of sound could thus be rotated around each loudspeaker in turn.

4. ANALYSIS AND RESYNTHESIS

In considering the characteristics of the *Rotationslautsprecher*, the discussion has stepped beyond a specific focus on tape-based spatialisation, and this expanded perspective can profitably be explored a stage further, taking into consideration some of the key aspects of the underlying *techné* as it was applied to the materials themselves. During the 1990s, inspired by the fruits of some investigative research into novel synthesis methods during the 1980s, Michael Clarke turned his attention to both the technical characteristics and the underlying compositional aesthetic of this work, starting in the first instance with the issues raised in this context in Stockhausen's article 'The concept of unity in electronic music' (Stockhausen 1962).

Clarke's account of his own investigations, published in 1998, provides an important endorsement for one key aspect of the current line of enquiry. He notes that:

> . . . the tape part of *Kontakte* . . .has a vibrancy often lacking in electronic music, and this article therefore sets out to investigate whether any significant points of contact can be discovered between Stockhausen's techniques of the 1960s and those of today's computerised studio . . . (Clarke 1998: 222)

From the preceding study it will be clear that the special techniques of sound projection and manipulation in space that were employed may provide some useful

[6]Very little use seems to have been made of this device by composers at the Paris Studio. Since, as already noted, all works were recorded in a mono format until 1958, its only practical use could have been in performance situations.

pointers. Clarke, however, starts from a much deeper level within the compositional process, notably the relationship of the microstructure at the lowest level of synthesis to the associated macrostructure, a consideration which is of particular significance in the composition of *Kontakte*. Here Stockhausen provides an important insight into his working methods when composing with tape:

> Intensity was controlled by regulating, with the aid of a voltmeter, the voltages recorded on tape (whereby the spectrum itself automatically varied with the variations in intensity), whereas duration was determined simply by the length of tape on which a sound was recorded. (Stockhausen 1962: 39)

The consequences of relying upon precise measurements of time by means of measuring the lengths of tape used with a ruler, whilst at the same time relying upon the almost unquantifiable elements of interpretation resulting from the regulation of intensities by means of manual control, will be considered further in due course. The key consideration for Clarke, already explored to a more limited extent in *Gesang der Jünglinge*, was the causal relationships between the inner durational structure of impulses, and the complex sound spectra that result when suitably irregular patterns of impulses are accelerated into the audio spectrum. Whereas modern digital technologies provide a number of ways of synthesising material in this manner, Stockhausen was entirely dependent on the functional characteristics and idiosyncrasies of the tape recorder. As Clarke observes:

> In practice, Stockhausen would record pulses produced by a pulse-generator onto tape and, by cutting and splicing, form these into a repeating tape loop. He would then accelerate the repeating sequence using a variable-speed tape recorder, often rerecording the result and repeating the acceleration process many times over to achieve the desired speed. In this way he was able to make transformations between pulses and frequencies, rhythms and timbres in a single continuous movement, as if part of one spectrum. (Clarke 1998: 223)

Clarke's curiosity with this method of impulse generation led to the discovery that the physical principles involved in this method of synthesis had many features in common with the impulse-based digital algorithm FOF he developed during the 1980s as an additional unit generator for the software synthesis program Csound. Whilst adding the caveat that the intention of his experiment was 'not to replicate the original but rather to demonstrate that the techniques used by Stockhausen are still available today in digital form' (*ibid.*: 230), he tested the proposition by synthesising a one-and-a-half minute segment of *Kontakte*, part of the score fragment reproduced and discussed in Stockhausen's article, starting at 16' 56.5" (Stockhausen 1962: 19–20).

The result is extraordinary in its likeness to the original. And yet there is something slightly different. Clarke himself gives an important clue as to why, when he notes that:

> Stockhausen's analogue technique resulted in the separate creation of each pulse stream. . . . However the mixing of pre-synthesised streams did not allow him to have precise control over the synchronisation of the streams at the micro level. At the mixing stage, synchronisation depended on the visual alignment of tapes on different machines and was then subject to fractional differences in the starting mechanisms and speed of these machines. Although such differences were not of significance in terms of normal mixing procedures, they would not have provided the control necessary for the synchronisation of streams so as to ensure the precise alignment of pulses. (Clarke 1998: 230)

Precisely, or rather imprecisely: the very fact that such precision was not possible identifies a crucial aspect of the *techné* that shaped and ultimately determined the compositional process. The issue here is whether indeed it is the very precision provided by modern day digital technology that removes a vital ingredient in terms of shaping the compositional aesthetic. To be deliberately provocative, perhaps it is the imprecision associated with the use of analogue technology that indeed accounts for the 'vibrancy lacking in electronic music' (*ibid.*: 222). No conclusions will be drawn here, for the research evidence presented here is insufficient to come to a definitive view one way or the other. The case for investigating these issues further, however, is compelling. Indeed it becomes irresistible when the proposition is tested a stage further.

In 1972, the Elektronmusikstudion (EMS) in Stockholm completed the construction of a revolutionary studio that combined the flexibility of a digitally controlled oscillator bank and associated processing devices with the power and versatility of a PDP 15 computer, used to program the operation of the system. As a test of its capabilities, a decision was taken to re-synthesise Stockhausen's *Studie II*, a work composed at Cologne in 1954. This task required the meticulous translation of the detailed construction score into the control language that had been specifically developed for operating the devices in the studio, known as EMS1. Stockhausen subsequently visited the studio, and this realisation was played to him. He was completely dismayed, observing that:

> Some time ago I suffered a terrible shock listening to my *Elektronische Studie II* (*Electronic Study II*) in the electronic music studio at Stockholm University, which has a very up-to-date synthesizer. It was a performance realised, according to the instructions published in the score, but without my collaboration. Well, what happened? It was awful. A farce, to say the least, a caricature of the work. You could say goodbye to the precision of the microtempi! And goodbye to the subtleties, to the

> movements of the spirit — all unjustified 'omissions', since the score was supplied with precise rhythmic and dynamic annotations regarding duration, volume, and the characteristics of the timbre. Instead of which there was nothing. Why? Because they let the computer handle the dynamic curves of the sound (*Hüllkurven*) which I had regulated, on the contrary, with manual controls. Hence the static quality. (Tannenbaum 1987: 22)

These observations provide cogent evidence of the significance of *techné*, indeed the very ways in which 'The composer's relationship to the materials and forms of his/her art . . . are mediated by those design tools' (Di Scipio 1995b: 374). By 'precision', Stockhausen does not mean the exact replication of the measurements recorded in the construction score, but all the tiny variations that occurred when cutting and splicing tape. Similarly, the manual control of amplitudes introduced subtleties of interpretation unique to the composer, which cannot be deduced from the score. Thus we arrive at a key issue identified with not a little irony by Landy in questioning of the value of 'rewinding the tape' (Landy 1999: 63): that is, what is the relevance of studying the 1940s and 1950s for composers of today?

The proposition, on the evidence provided above, is that there is still much to be investigated here, with the dual prospect of both gaining a more informed understanding of the repertory of past and also facilitating the rediscovery and reinterpretation of past practices which might open up new ways of interacting and working with modern technologies. There are therefore compelling reasons for acquiring a much more informed understanding of the *techné* of electroacoustic music than has hitherto been the case, with particular reference to the characteristics associated with works produced during the formative and in many respects the defining years of the medium.

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